



# Passive Gas-Gap Heat Switches for use in low-temperature cryogenic systems

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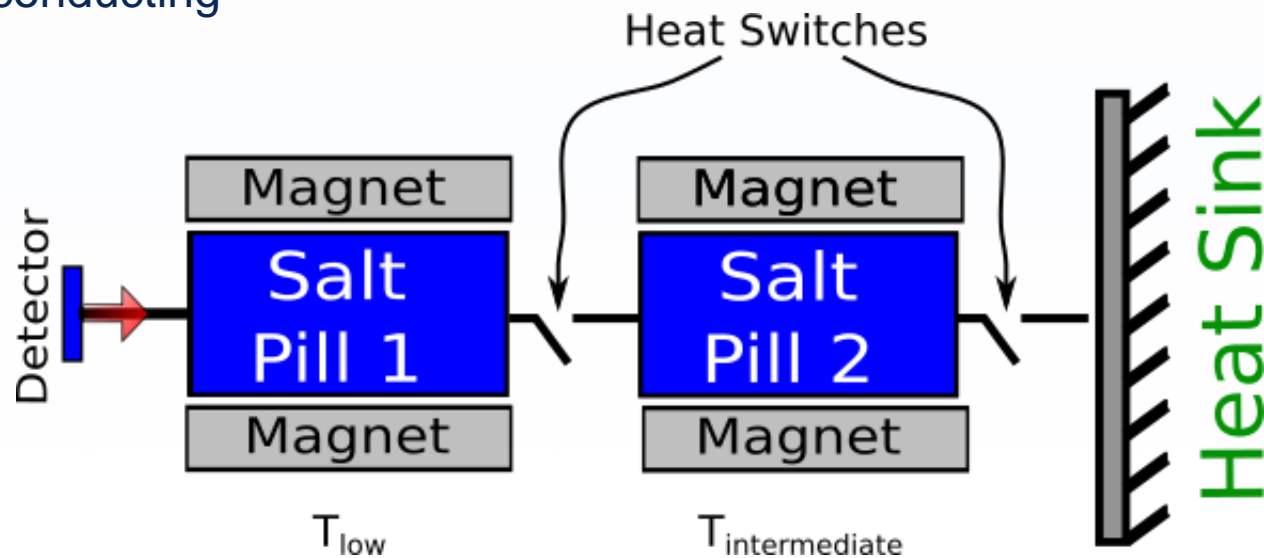
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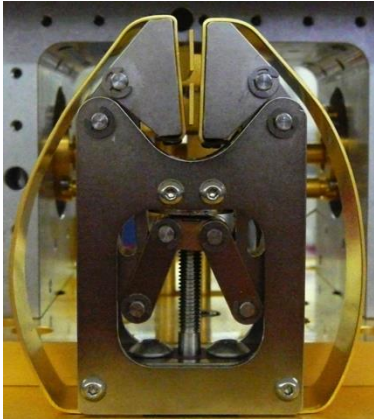
# Why Heat Switches



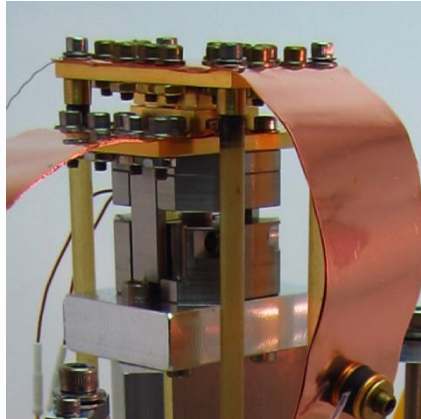
- Any cryogenic system that needs to have a predictable controlled flow of heat requires a form of a heat switch
- Come in many forms
  - Mechanical
  - Gas Gap
  - Superconducting



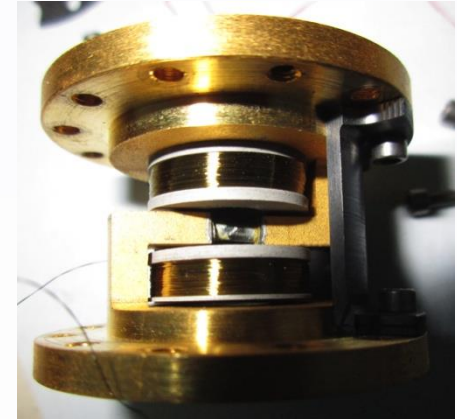
# Heat Switches in Cryogenics Systems



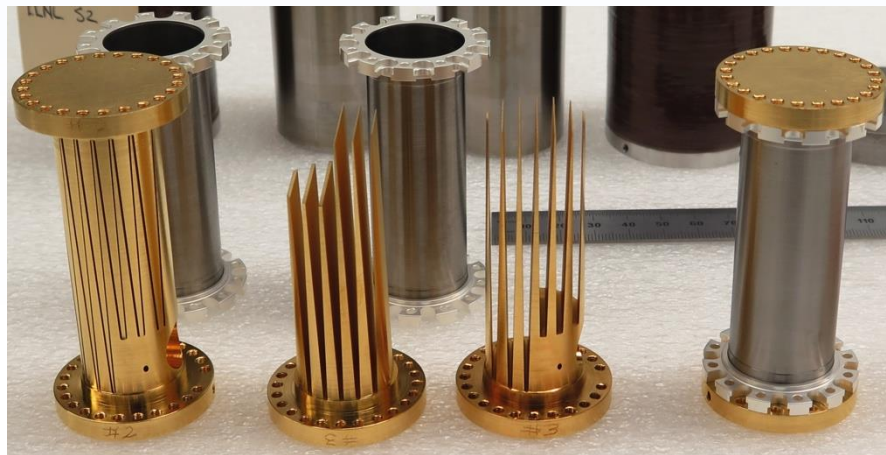
Mechanical



Electro-Mechanical

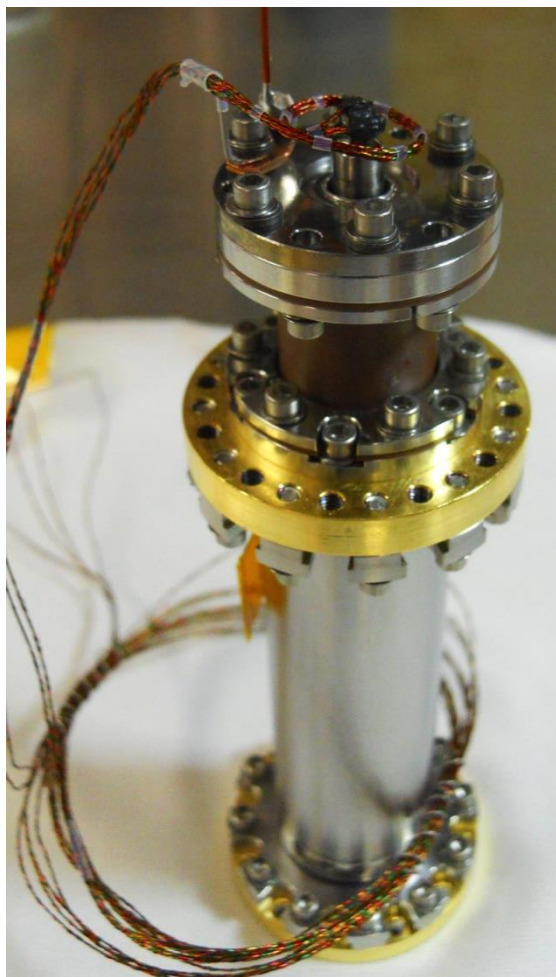


Superconducting

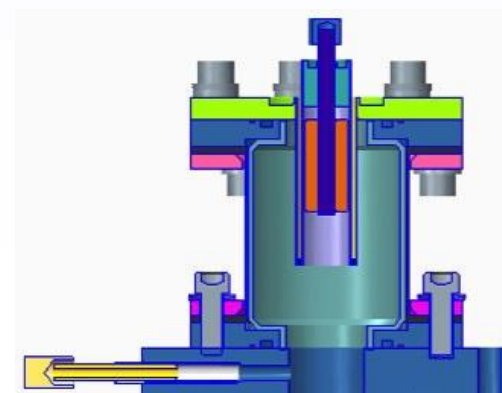
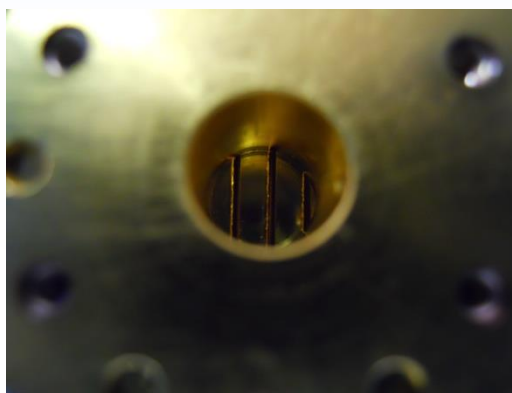


Gas Gap

# Active GGHS



- A large-surface area getter absorbs gas below some temperature evacuating the region between the two sets of fins
- Getter temperature controlled by a heater in thermal contact with the getter
- Below 10 K, bituminous charcoal is a good choice— used on Astro-H

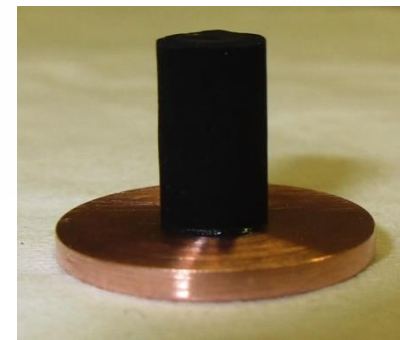
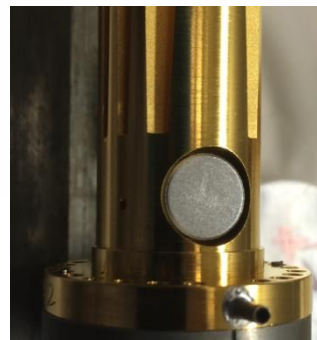


# Passive GGHS



No separate input needed to activate switch

- Switch state controlled by temperature of a getter
  - For us, often controlled by an ADR stage temperature
- For our use, choice of getter material dictated by temperature range of intended use
  - Charcoal (“high” temperature)
  - Sintered stainless steel puck (~ 1 K)
  - Gold-plated copper fins provided by innards (~ 0.16 K)





# Benefit of a PGGHS



- More simple control system
  - No need to activate a getter heater
  - No need to measure a getter temperature
- Since no additional heat is added to the system to activate the switch, more thermodynamic efficiency
- Rapid on / off times
- More compact
  - no external getter housing

# Contributions to Switch Conductance

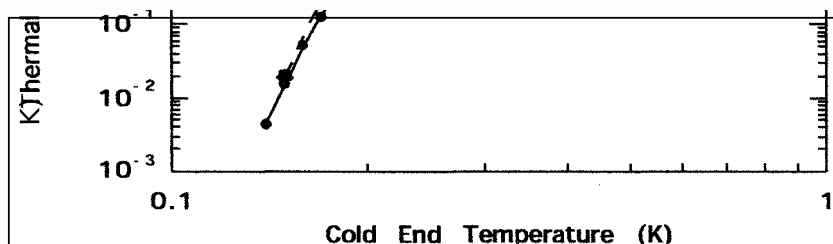


FIG. 2. Measured (●) and calculated (◆) thermal conductance of the low temperature passive gas gap switch. The separate contributions to the calculated conductance are also shown: copper (△), Kapitza boundary resistance (○), and the gas (□).

the heater power. Low power was used to not overload the ADR. The conductance of the switch as a function of cold end temperature is shown in FIG. 2. Data taken for different heater powers show the heat flow to be linear with temperature, and the conductance therefore dependent only on the cold end temperature. When the temperature of the cold end fell to 0.13 K and below the conductance was indistinguishable from the background heat flow in the heat switch shell. The hot end of the switch was heated to above 1.3 K.

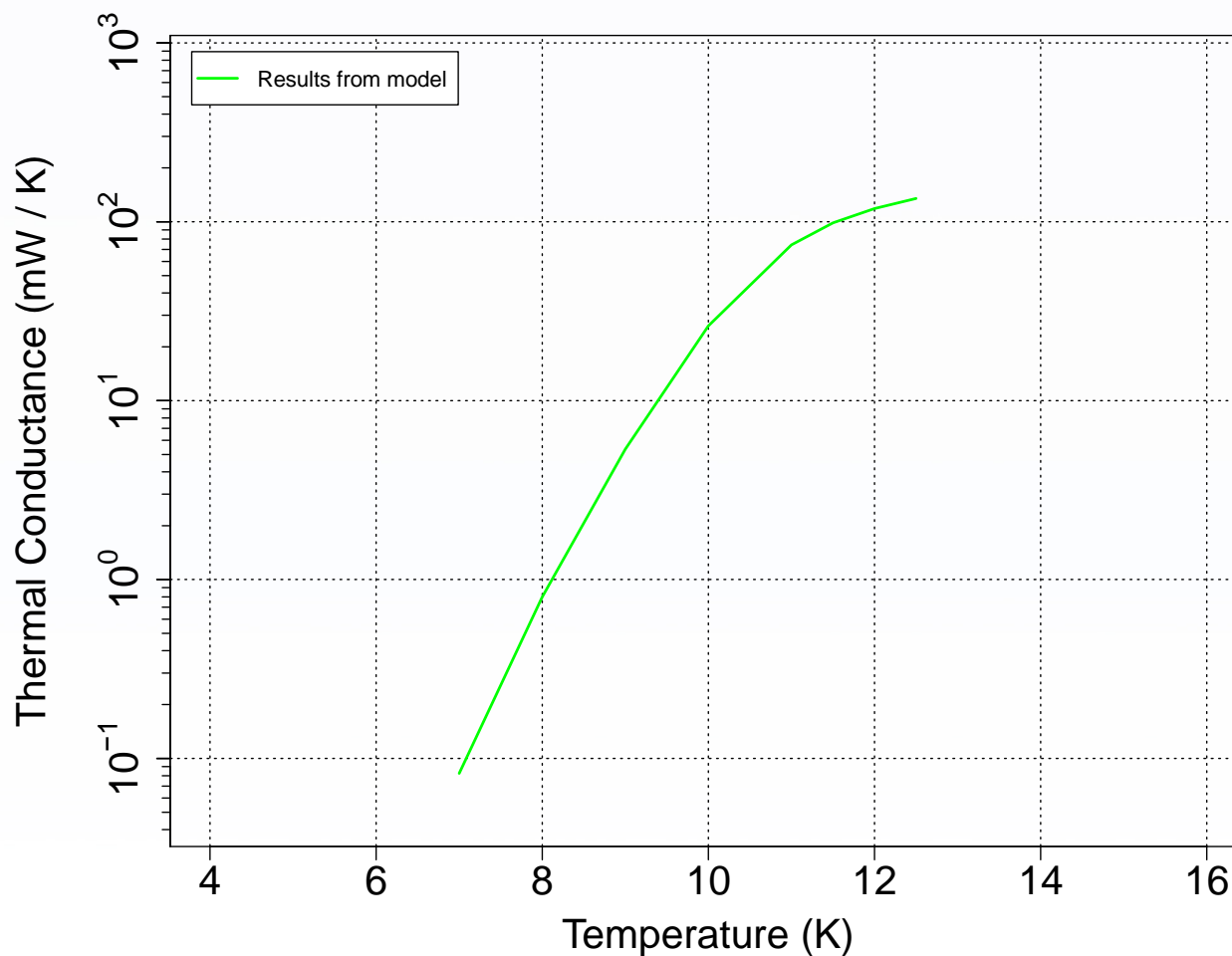
These data are compared to calculations of the Kapitza boundary resistance.

Source: Shirron, Canavan, DiPirro et al.,  
**Passive gas-gap heat switches for use in  
adiabatic demagnetization refrigerators**

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(2002)

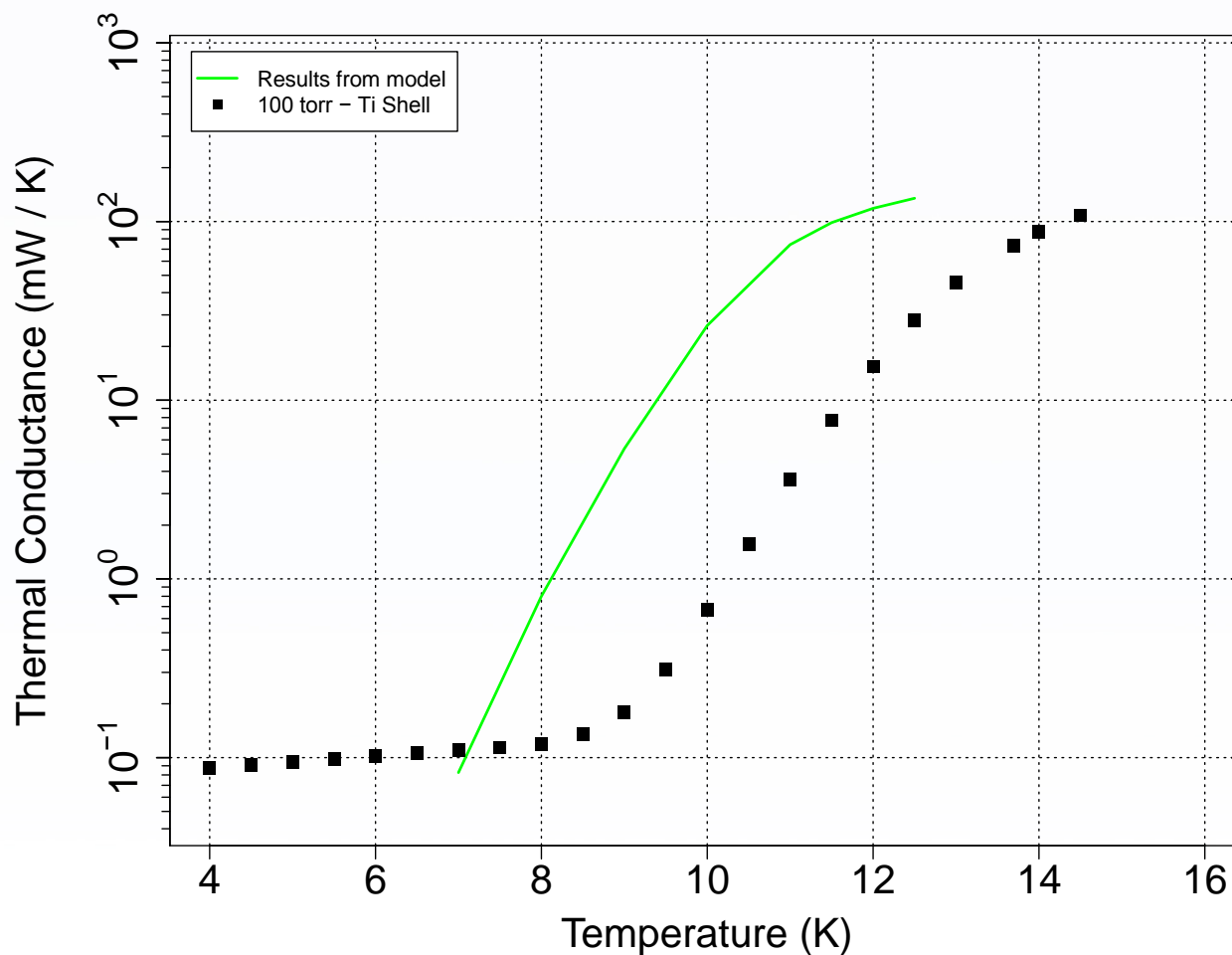
- On-state conductance has many contributions
  - Conductivity of the copper fins
  - Conductivity of the gas between the fins
  - Boundary resistance between the gas and copper fins
  - Boundary resistance between the switch and other components
- Off-state conductance dominated by the hermetic outer shell
  - Typical “Low-temperature” switches use titanium (superconduct below ~3.4 K)
  - Higher temperature switches may use stainless steel

# Switch Developed for “10 K ADR”

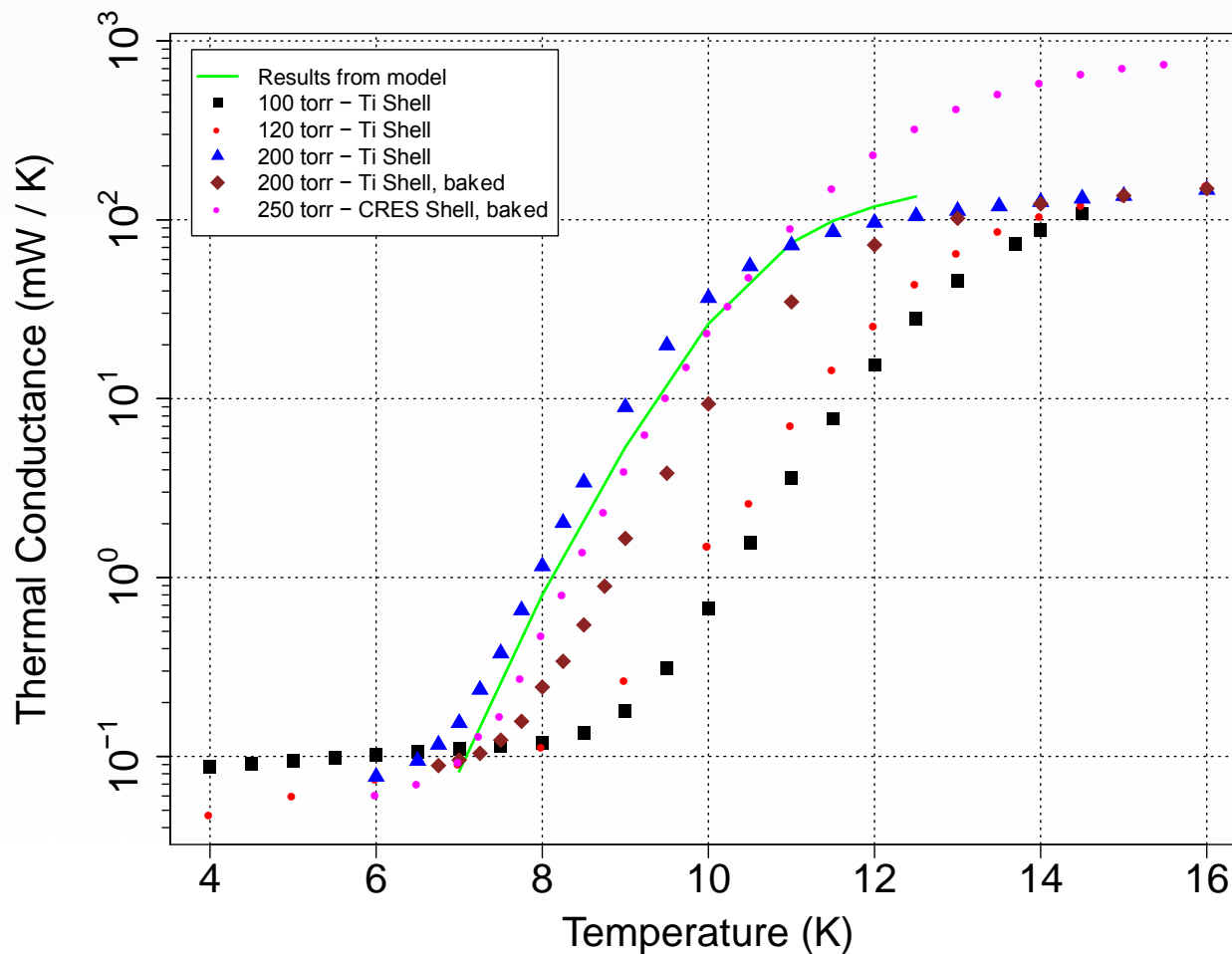




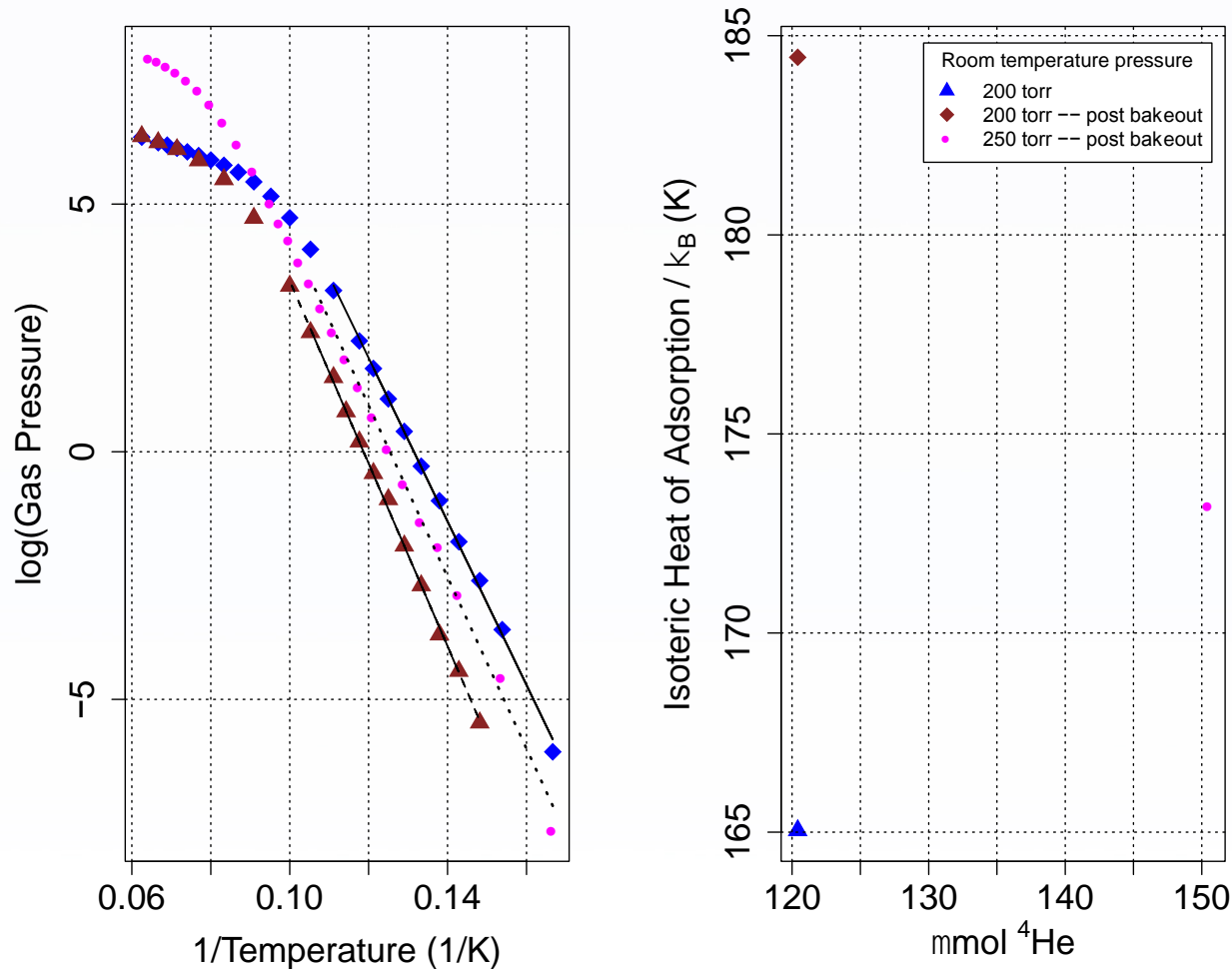
# Switch Developed for “10 K ADR”



# Switch Developed for “10 K ADR”



# Isosteric Heat of Adsorption





- Presented passively-activated gas-gap heat switches with transition temperatures ranging from 0.16 to 10 K
- Wide temperature range provided by choice of gas and getter material
- Compact size, rugged, thermodynamically efficient
- Currently in use in multi-stage adiabatic demagnetization refrigerators at NASA/GSFC